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A CLOSED SYSTEM OF REPRESENTATION FOR RELATIONALLY-ORGANIZED DA--ETC(U)

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A CLOSED SYSTEM OF REPRESENTATION FOR

RELATIONALLY-ORGANIZED DATA AND ITS DESCRIPTORS

Clifford R. Hollander

Technical Note No. 53

December 1974

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Digital Systems Laboratory
Departments of Electrical Engineering and Computer Science
Stanford University
Stanford, California

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## Abstract

Recently we have witnessed a dramatic increase in both the study and use of data bases. These activities have in turn stimulated interest in data description facilities. The work reported here was motivated by the observation that descriptors for structured data are themselves, in fact, "data-like" in many respects. This paper introduces a simple language for relationally-organized data and a companion descriptor language, for the purpose of demonstrating a single system of representation for both data constructs and their descriptors. It is assumed that each data construct (i.e., relation) belongs to a previously defined relation class and that a descriptor is used to define the structure of the elements of each class. The system presented here is "closed" in the sense that it allows each descriptor to be represented as a relation. Its adoption would permit data description facilities to be implemented in terms of data manipulation facilities.

Key words and Phrases: Data description, relation, descriptor, relation class, closed descriptive system.

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## Introduction

Non-procedural data description languages (DDLs) have emerged in conjunction with more flexible schemes for organizing data. Some DDLs (e.g., [1,2]) were tied to a particular procedural host language (e.g., COBOL). Others (e.g., [3,4]) supported only specific classes of data structures. The most general DDLs (e.g., [5,6]) were host language independent and/or embraced a wide spectrum of data organizations (e.g., hierarchical, relational, network). In each case, however, the facilities for constructing data descriptors were kept separate from those for handling the data itself.

The work reported here is an adaptation of methods applied earlier to hierarchical data structures [7]. It was motivated by the observation that descriptors for structured data are themselves, in fact, "data-like" in many respects. We introduce a simple data language and a companion descriptor language, for the purpose of demonstrating a single closed system of representation for both data constructs (i.e., relations) and their descriptors. It is assumed that each relation belongs to a previously defined relation class and that a descriptor is used to define the structure of the elements of each class.

The system is "closed" in the sense that it allows each descriptor to be represented in terms of a relation whose structure is, in turn, specified by means of a second-level descriptor. Closure is achieved because a single relation class is found whose own structure is sufficiently

general to accomodate the data representation of any descriptor, including its own. Transformations are defined, relating the descriptor and data representations for a descriptor.

An obvious benefit could be derived from a scheme such as the one proposed here. Its implementation would permit a single set of data manipulation facilities (e.g., [4,5]) to suffice both for building elements of existing relation classes and for defining new relation classes themselves.

## A Relational Data-Descriptor Language Pair

We require a framework within which to discuss the relationship between data and the descriptors which serve to define its structure. Let us therefore introduce a language of relational data structures (i.e., relations) and a complementary descriptor language. It is important to remark at this point that this paper is deliberately incomplete in its treatment of relational data bases; we are focusing here upon certain aspects of the description of relationally organized data, whereas we ignore its manipulation. For a more thorough treatment of the theory and potential of the relational approach to data management, the reader is referred to [3,4,8].

We consider a data language consisting of <u>relations</u> defined over (not necessarily distinct) sets (called <u>domains</u>) $D_1, D_2, \ldots, D_n$. To be consistent with [9], we shall require that each $D_k$ contain only simple, non-aggregate values; <u>integers</u> and <u>identifiers</u> would be examples of such

domains. A relation R over $D_1, D_2, \ldots, D_{n_R}$ is a subset of the cartesian product $D_1 \times D_2 \times \ldots \times D_{n_R}$. The number of domains involved, $n_R$, is referred to as the degree of R. Stated another way, R is a set of tuples, each of the form $<d_1, d_2, \ldots, d_{n_R}>$ where $d_i \in D_i$. For convenience (and to distinguish between nondistinct domains), a unique role name, $id_k$, is associated with each domain, $D_k$, which underlies R. A role name is used for accessing the corresponding component of any tuple $r \in R$ (i.e., $id_k[r]$ selects the k-th component of r). We shall denote the current set of relations by $\mathfrak{R}$.

We shall define the structure of each relation by means of descriptor. A separate language is used for formulating these descriptors. This language must allow us to specify the domains and role names from which a relation is built. To define a relation $R \in \mathfrak{R}$ we use a descriptor ds(R) which takes the form of a tuple of named domains

$$\underline{ds}(R) = <id_1 : D_1, id_2 : D_2, \ldots, id_{n_R} : D_{n_R}> \tag{1}$$

where each $D_k$ is a domain and the corresponding $id_k$ is its role name relative to R. We let $\mathfrak{D}$ denote the current set of descriptors. It is important to distinguish between $\mathfrak{D}$ and the set of all possible descriptors; while the latter depends only upon the descriptor language, the former depends upon $\mathfrak{R}$ as well. We can express the assumed relationship between data (relations) and descriptors in terms of a mapping

$$\text{DESCRIBED\_BY} : \mathfrak{R} \rightarrow \mathfrak{D} \tag{2}$$

where as we have observed above $\mathfrak{R}$ and $\mathfrak{D}$ vary with time. Each descriptor D

actually defines the structure of set of relations, called a <u>relation class</u>. Formally speaking, the relation class is the inverse image of D under DESCRIBED_BY, i.e.

$$\text{DESCRIBED\_BY}^{-1} : \mathfrak{D} \rightarrow \{\text{relation classes}\}. \qquad (3)$$

Fig. 1 displays an example relation, EMP, and the corresponding descriptor <u>ds</u>(EMP); EMP might be used to hold employee information. EMP is defined over four nondistinct domains: two instances each of a domain <u>name</u> and a domain <u>integer</u>. For convenience EMP is displayed using a tabular format with one column, labelled by a role name, for each domain (instance). It should be noted that the order of appearance of the rows (i.e., tuples) in the table is irrelevant.

## A Data Representation for Descriptors

Within the framework established in the previous section, any extension to $\mathfrak{R}$ to define a new data relation class requires that a new descriptor D be created and included in $\mathfrak{D}$. We discuss here a transformation technique whereby any descriptor can be represented as a relation. The importance of this technique is that it facilitates extensions to $\mathfrak{R}$ by reducing the problem of creating a new descriptor to one of building an element of a previously defined relation class. We let <u>rn</u>(D) denote the relation by which we represent D.

For a relation to be used to represent descriptor information, its own structure must be specified by a descriptor. This would seem to lead, unfortunately, to a system requiring an infinite number of descriptor levels, (i.e., a relation R, described by a descriptor <u>ds</u>(R), represented as a relation <u>rn</u>(<u>ds</u>(R)), described by a descriptor <u>ds</u>(<u>rn</u>(<u>ds</u>(R))), ...). However,

this situation can be avoided if a single relation class can be found to accomodate the data representation of any descriptor, including the one that defines the structure of (each element of) the relation class itself.

We recall from eq. (1) that a descriptor D is an n-tuple of identifier-domain pairs. We can represent each element of D by means of a 3-tuple of the form

$$\langle k,\ id_k,\ domain_k \rangle \tag{4}$$

where k indexes a position within D. Having made this observation, let us now define a relation, denoted by rn(D) whose tuples are given by eq. (3) for k = 1,2,...,n. For example the result of applying this technique to the descriptor ds(EMP) in Fig. 1 is

rn(ds(EMP)) =

| INDEX | ROLE | DOM |
|---|---|---|
| 1 | NAME | name |
| 2 | SAL | integer |
| 3 | MGR | name |
| 4 | CODE | integer |

(5)

We note that for any descriptor D, rn(D) has degree 3 and is defined over domains integer,† identifier,† and domain;* as in eq. (5), we shall use INDEX, ROLE, and DOM as their respective role names. The descriptor for rn(D), namely ds(rn(D)), is given by

<INDEX:integer, ROLE:identifier, DOM:domain> (6)

† Note that both of these domains serve as candidate keys [8] for such a relation.

* This use of a domain-valued domain (i.e., a domain whose elements are domain names) is very much akin to the use of mode-valued modes in programming languages such as ALGOL 68 [10].

EMP:

| NAME | SAL | MGR | CODE |
|---|---|---|---|
| J. Smith | 10 | W. Harris | 7 |
| F. Mills | 21 | A. Kelly | 13 |
| L. Tan | 11 | F. Mills | 9 |
| W. Harris | 19 | A. Kelly | 14 |
| P. Jones | 12 | W. Harris | 9 |
| R. Simms | 13 | F. Mills | 8 |

(a) Tabular Form of EMP

<u>ds</u>(EMP) = <NAME:<u>name</u>, SAL:<u>integer</u>, MGR:<u>name</u>, CODE:<u>integer</u>>

(b) Descriptor for EMP

Fig. 1. A Sample Relation, EMP

The important thing to notice about eq. (6) is that it does not depend upon D. So that regardless of the original descriptor D to which this representation scheme is applied, it always yields a relation in the relation class defined by the descriptor in eq. (6). For convenience, let us denote this "descriptor-descriptor" by $D_{super}$. To demonstrate that we have indeed achieved the desired closure with respect to descriptor levels, we apply the transformation $\underline{rn}(\cdot)$ to $D_{super}$ yielding

$\underline{rn}(D_{super})$ =

| INDEX | ROLE | DOM |
|---|---|---|
| 1 | INDEX | <u>integer</u> |
| 2 | ROLE | <u>identifier</u> |
| 3 | DOM | <u>domain</u> |

(7)

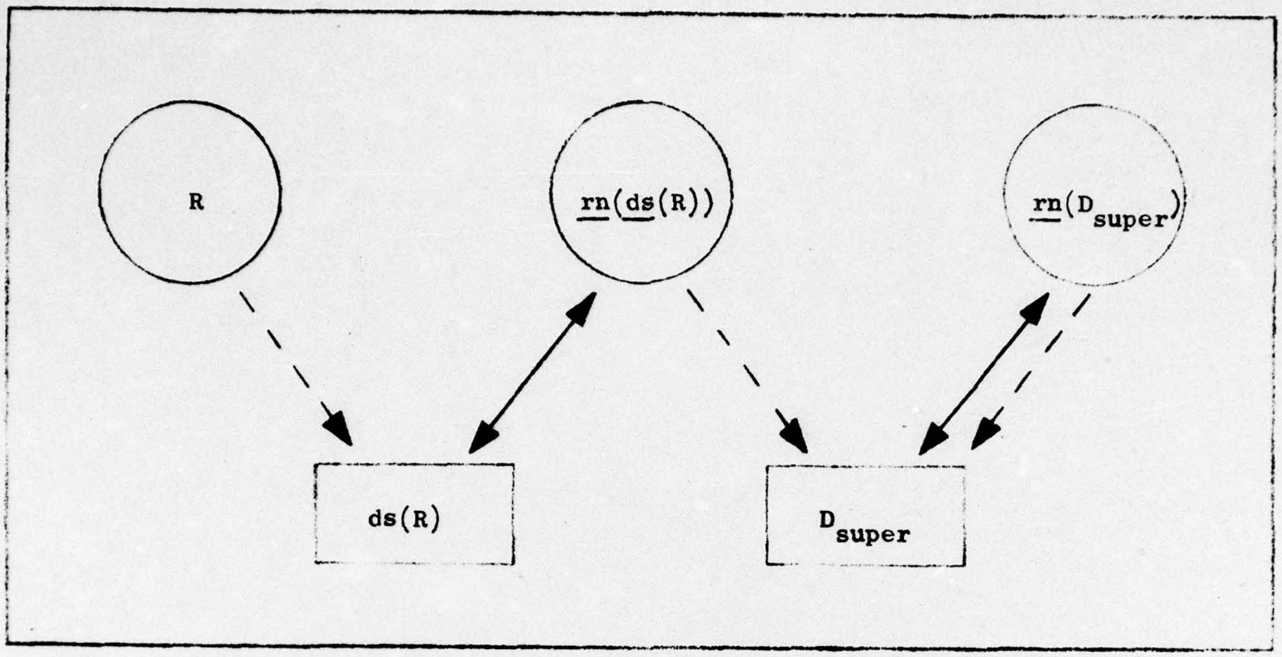
and we observe that $D_{super}$ is a fixedpoint [11] of the composite transformation $\underline{ds}(\underline{rn}(\cdot))$, i.e.,

$$\underline{ds}(\underline{rn}(D_{super})) = D_{super}. \tag{8}$$

Clearly it is a straightforward matter to define an inverse transformation to <u>rn</u> for recovering the descriptor representation of a descriptor from its data representation. Fig. 2 diagrams the relationships that exist between the various constructs arising from a typical data relation (e.g., EMP).

## Conclusions

We have examined a transformation technique by which descriptors can be represented as data relations. Although the technique is demonstrated only for a particular choice of data and descriptor languages, it is clear that



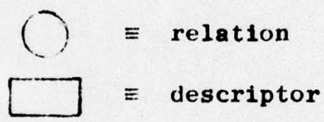




Fig. 2. Descriptive environment of a relation R.

it can be generalized to a broad class of data/descriptor language pairs. It is in fact applicable to any pair in which the data language constructs are sufficiently powerful to encode the variability of structure exhibited by the set of descriptors.

The result of employing such a technique is a single closed system of representation for both data and the descriptors which define the structure of that data. The benefit derived from adopting this kind of system is that it would allow a data description facility to be completely subsumed by (or defined in terms of) a data manipulation facility.

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